University of Groningen

The rational weakness of strong ties

Flache, Andreas

Published in:
Journal of Mathematical Sociology

DOI:
10.1080/00222500212988

Journal of Mathematical Sociology, 26: 189–216, 2002

0022-250X/02 $12.00 + .00
DOI: 10.1080/00222500290047106

THE RATIONAL WEAKNESS OF STRONG TIES: Failure of Group Solidarity in a Highly Cohesive Group of Rational Agents

Andreas Flache
Interuniversity Center for Social Science Theory and Methodology—ICS, University of Groningen, The Netherlands

Recent research (Flache, 1996; Flache and Macy, 1996) suggests a "weakness of strong ties." Cohesive social networks may undermine group solidarity, rather than sustain it. In the original analysis, simulations showed that adaptive actors learn cooperation in bilateral exchanges faster than cooperation in more complex group exchanges, favoring ties at the expense of the common good. This article uses game theory to demonstrate that cognitive simplicity is not a scope condition for the result. The game theoretical analysis identifies a new condition for the failure of group solidarity in a cohesive group. Task uncertainty may make rational cooperation increasingly inefficient in common good production. Accordingly, rational actors may increasingly sacrifice benefits from common good production in order to maintain social ties, as their dependence on peer approval rises.

Keywords: Group solidarity, Social dilemmas, Social control, Agency theory, Game theory, Imperfect information, Computer simulation

INTRODUCTION

It is almost a truism for theories of solidarity that strong social ties further group solidarity.[1] Collective action research shows that dense networks of

For their useful comments and criticism the author is indebted to Gerald Mackie, two anonymous reviewers, and the members of the ISCORE and ICS-KLI research teams at the Universities of Utrecht and Groningen, in particular Vincent Buskens, Werner Raub, and Frans Stokman. This research has been made possible by a fellowship of the Royal Netherlands Academy of Arts and Sciences.

Address correspondence to Andreas Flache, ICS—University of Groningen, Grote Rozenstraat 31. NL-9712 TG Groningen, The Netherlands. E-mail: a.flache@ppsw.rug.nl

[1]Following Hechter (1987), I view group solidarity here as contribution to common goods that benefit every member but require a joint effort to be produced (cf. Olson, 1965; Ostrom, 1990; Petersen, 1992). This distinguishes group solidarity from solidarity that pertains to a relationship between two individuals, such as fairness in sharing, help in need situations or refraining from breaching promises (Lindenberg, 1998). It is the central topic of this analysis to address the potential conflict between the common good and the relational arena of solidary behavior in groups.

communication and interaction greatly facilitate group mobilization in political uprising or strike movements (Opp and Gern, 1993, 673; Gould, 1993, 734–740; Marwell and Oliver, 1993, 104). Similarly, in the workplace social ties are known to foster group tasks. Coleman (1994) points out that Japanese firms often create "company towns" and "common recreational facilities" for their employees "designed to simultaneously strengthen loyalty to the company and social ties among employees" (173). Petersen (1992) concludes in an overview of the literature that "the evidence provided by industrial sociologists is that social rewards can be quite important in regulating behavior" (341).

Recent work (Flache, 1996; Flache and Macy, 1996; Kitts et al., 1999; Flache et al., 2000) argues that the relationship between group solidarity and strong ties is more complex than the literature has it. These studies suggest a "weakness of strong ties." Cohesive networks may often undermine group solidarity rather than sustain it. The argument focuses on the desire of actors to obtain social rewards, such as affection or approval, from other group members. This desire may compromise actors' willingness to impose social control, because enforcers may fear to loose valued rewards from deviants. However, Flache and Macy's argument hinges critically on the assumption that agents possess extremely low cognitive capacities. Their simulations showed that "backward looking" adaptive actors learn cooperation in bilateral social relations faster than cooperation in more complex group exchanges, favoring emergence of strong ties at the expense of the common good. This article generalizes the argument. I show that cognitive simplicity is not a scope condition for the weakness of strong ties. I use a game theoretical model in the tradition of recent work in agency theory that combines the analytical precision of rational choice theory with sociologists' attention for informal incentives (Holländer, 1990; Kandel and Lazear, 1992; Spagnolo, 1999; Loch, Huberman and Stout, 2000). The analysis highlights task uncertainty as a new and empirically plausible condition under which even strategically rational actors may fail to effectively organize peer pressure in highly cohesive groups.

The article uses the potential conflict between task and ties at the workplace to illustrate the argument, but the scope is more general. The conflict between common interest and social relations has not only been overlooked in studies of work group behavior (Petersen, 1992) but also in analyses of group solidarity and collective action (Hechter, 1987; Marwell and Oliver, 1993). Section 2 discusses the theoretical background. Subsequently, I present the formal model of team production and social interaction. Section 4 then deals with game theoretical analysis of the model and section 5 presents results.

TIES VS. TASK: CONFLICTING THEORETICAL VIEWS

At the workplace, the problem of group solidarity centers on the "workers' dilemma" whether to "work" or "shirk." Workers share a common interest in maximizing productivity if, for example, weak performance by the firm leads to the loss of jobs, or wages are tied to production norms by bonus payments or group piece-rate schemes (Edwards and Scullion, 1982, 182). At the same time, workers face an individual incentive to "free ride" by "shirking" while others shoulder the burden of maximizing task performance (Olson, 1965; Alchian and Demsetz, 1972). Homans (1974) argued that peer pressure may be the central mechanism to attain group solidarity in such a social dilemma[2] (Dawes, 1980). Strong ties give members the leverage to serve as taskmasters, praising hard workers and ostracizing shirkers. Correspondingly, most researchers have assumed that this effect of social pressure on collective action is moderated by members' dependence on the group for social approval (Seashore, 1954; Festinger, Schachter, and Back, 1950; for an overview of empirical studies, see Lott and Lott, 1965). That is, as member dependence on peer approval increases, social sanctions will become more effective as catalysts of group solidarity.

Flache and Macy (1996) argued that the theory of compliant peer pressure through strong ties is flawed. The potential collective benefit from effective social control is no guarantee that members of a group-rewarded production team will be willing to enforce work norms, due to the "second-order free-rider problem" (Oliver, 1980). Friends with few outside sources of social support may be reluctant to risk personal relationships by using approval as an instrument of social control. Computer models of the evolution of friendship networks (Flache and Macy, 1996; Flache, 1996; Kitts, Macy, Flache, 1999) support this conclusion. The simulations replicated Homans' prediction that social pressure may solve social dilemmas if actors use approval to selectively reward good behavior. However, if agents are allowed the option to offer unconditional approval to their peers, dyads tend to form in which both sides approve of each other while the interactants neglect investments in the common good. As a consequence, a cohesive informal network may arise, while at the same time the group fails to achieve group solidarity.

[2]Social dilemmas may also arise under work group norms that discourage high effort, such as quota restriction norms (Homans, 1951, 79). The analysis of social control failure applies to both norms of production and quota restriction, because in both cases high dependence on peer approval may deter workers from imposing social pressure on deviants. To facilitate presentation, I focus in the remainder on the dilemmas created by production norms.

Flache (1996) confirmed this weakness of strong ties in laboratory experiments.[3]

The analysis of the weakness of strong ties opens up an intriguing new view on the relationship between social relations and group solidarity. However, the theoretical argument suffers from a potentially severe limitation of scope. Flache and Macy (1996) assumed "stochastic learning" (Bush-Mosteller, 1955), a rather extreme—if not empirically implausible—representation of bounded rationality (Simon, 1955). In this model, actors make choices exclusively on basis of a simple "trial and error" rule, entirely refraining from anticipation of the consequences of their actions. In addition, the model uses "satisficing" actors (Simon, 1955), who deem suboptimal outcomes as "good enough" rather than searching for a better solution. Only this combination of stochastic learning with satisficing generates the prediction of social control failure. In the computer analysis (Flache and Macy, 1996), strong ties quickly stabilized after backward-looking actors coordinated in a random search on the rewarding outcome of mutual approval (relational cooperation). The coordination of this "stochastic collusion" (Macy, 1989, 1991) in bilateral exchanges is simple as compared with the coordination of groupwise cooperation in common good production (task cooperation). As a consequence, strong ties of mutual approval arise in the simulated team well before stochastic collusion in the work task. With sufficient dependence on peer approval, satisficing actors then deem the outcome of strong ties good enough despite failure of common good provision.

Subsequent game theoretical analyses tested the robustness of the argument. (Flache, 1996; Flache et al., 2000). These analyses question the learning theoretical underpinning of the weakness of strong ties. Perfectly rational actors are not distracted from social control by strong friendship relations. Instead, under a large range of conditions, rational actors are capable of solving the complicated cooperation problem posed by simultaneous exchanges of approval *and* contribution to the common good (full cooperation). Mutual anticipation of rational behavior allows actors to engineer reciprocity in form of conditional full cooperation in repeated

[3] In the laboratory game, subjects made choices to invest in "work" and in "approval of a colleague." "Work" contributed to the collective welfare (group wage), while "approval" constituted a contribution to the colleague's personal welfare. The study compared two conditions. In one condition, unconditional approval was feasible, and in the other condition feedback was restricted so that only multilateral exchanges involving task contribution could arise. As expected, peer pressure, measured in terms of subjects' tendency to reward task contribution with approval, dropped significantly when unconditional approval was allowed (184). Accordingly, task contribution was lower and declined faster in that condition (169–179).

interactions (cf. Friedman, 1971, 1986; Axelrod, 1984, 1997; Voss, 1985; Taylor, 1987; Raub, 1988). When actors are sufficiently interested in future rewards, rational egoists refrain from shirking in the present, because they anticipate others' retaliation. In this perspective, strong ties enhance the sanctioning potential that members can mobilize to deter shirkers. Punishment strategies become feasible that impose on deviants not only the loss of future provision of the good, but also the loss of valued peer rewards. As a consequence, the threat of stronger sanctions stabilizes cooperation both in ties and task, consistently with traditional theories of informal control.

Despite the robustness of conditional cooperation between rational actors, backward-looking decision making may not be a necessary assumption to predict a weakness of strong ties. Even strategically rational decision makers may fail to mobilize strong ties for informal social control, if social conditions occur that exacerbate the potential conflict between task and ties. In particular, imperfect information about others' behavior may greatly compromise the effectiveness of social control. However, previous game theoretical analyses and simulations studies of social control (Heckathorn, 1989, 1990; Flache, 1996; Spagnolo, 1999; Flache et al., 2000) neglected this possibility and assumed perfect information.

In common good production, individual actors may occasionally fail to contribute to the collective task due to "idiosyncratic disturbances" (Bendor and Mookherjee, 1987; cf. Green and Porter, 1984; Fudenberg and Tirole, 1991). Bendor and Mookherjee highlight the complication that task uncertainty implies for task cooperation. Peer monitoring in organizations is often imperfect. Workers may observe only the ***results*** of colleagues' contributions to a group effort, but these results may be an unreliable indicator of actual efforts. For example, a member of a consultancy team works hard at home to deliver a report to an important client in due time, but a computer failure makes it impossible for the consultant to meet the deadline. Afterwards, colleagues can only tell that the consultant failed to contribute. As a consequence, "erroneous" defections may severely curtail efficiency of task reciprocity, because conditionally cooperative strategies need to impose at least some retaliation in order to credibly deter free riders (cf. Wu and Axelrod, 1995; Kollock, 1993).

The problem of imperfect information may be crucial for the conflict between task and ties. Multilateral task exchanges tend to suffer more from idiosyncratic disturbances as compared to bilateral social exchanges. The error probability increases with the number of participants, and monitoring is more effective in social relations that take place in face to face interactions. Accordingly, when full cooperation links ties to task performance in a noisy environment, the danger of unintended chains of mutual sanctions may put social ties under severe pressure. This increases the attractiveness of purely relational cooperation as an alternative solution for the group. The game theoretical analysis of this article shows how this problem of task-uncertainty renders the weakness of strong ties consistent with the notion of strategic rationality.

THE REPEATED TEAM GAME

The model of team production assumes that actors value wage payments and approval of their peers, and they rationally weight these values against the effort required to obtain them. Wage payments are tied to team performance i.e., the more workers contribute to the collective effort, the higher the payment. Actors face two decisions: whether to invest in collective effort ("work") and whether to invest in their relationships with other members of the group ("approval"). To simplify, I assume actors must choose between just two options for each decision: to work or shirk, and to approve or not approve. I refer to the aggregated amount of work contributions in the group as "task performance," while the aggregated amount of approval between group members is denoted "group cohesion." Group interaction is modeled as a repeated N-person game. Equation (1) represents the strategy of player i in iteration t of the game as vector σ_{it}

$$\forall i : \sigma_{it} = (w_{it}, a_{i1t}, \ldots, a_{iNt}). \tag{1}$$

The symbols i,j in (1) index actors, w and a identify each of the two decisions, work effort and social approval. The work decision of actor i in iteration t is denoted w_{it}, where $w_{it} = 0$ for shirkers and $w_{it} = 1$ for contributors. i's approval of j is indicated by a_{ijt}, where $a_{ijt} = 1$, when i approves of j and $a_{ijt} = 0$, otherwise. To preclude narcissism, the restriction $a_{ijt} = 0$ is employed. Within one iteration, actors take decisions simultaneously and independently.

Following Bendor and Mookherjee (1987), task uncertainty is modelled with a commonly known probability ε that due to some mishap an individual's contribution fails to be effective $(0 \leq \varepsilon \leq 1)$, where ε is equal for all group members. Hence, with $\varepsilon > 0$, a worker knows after every iteration t the *group output* in terms of the number of *effective* contributions in previous iterations t', but group members are not aware of the actual input $w_{jt'}$ of individual colleagues. At the same time, workers are assumed to be fully and perfectly informed on the approval actions $a_{jkt'}$ of all group members in previous iterations $t' < t$. This is a rather extreme assumption, but it greatly facilitates model analysis, while it still captures the substantive assumption that monitoring in social relations is more accurate and less vulnerable to "exogenous disturbances" as compared to group exchanges of task contribution. Finally, actors are perfectly informed on all other aspects of the game.

The expected payoff of actor i in iteration t of the game, u_{it}, results from both expected benefits from wage and approval and the costs of i's own effort and social actions. Two types of benefits may offset the effort or expense from hard work or from giving approval: a higher group wage and social approval by one's peers. Group wage is modelled as a linear function of aggregated individual outputs. Aggregated output may be lower than the number of actual effort investments due to task uncertainty. Each actor receives $1/N$th of the bonus earned by the group, regardless of contribution, where the output of one worker increases the group bonus by one unit. The second source of benefit is social approval from one's peers. I leave the complication of informal status hierarchies to future research and assume that for ego every colleague's contribution is equally valuable. Finally, when ego invests into the collective effort, his utility is diminished by work costs. In addition, a group member may incur some cost for every unit of approval he gives to one of his peers. Equation (2) formalizes the expected utility ego derives from the outcome of the approval and work decisions iteration t:

$$u_{it} = \sum_{j=1}^{N} \left(\frac{\alpha}{N} (1 - \varepsilon) w_{jt} + \beta a_{jit} \right) - c w_{it} - c' \sum_{j=1}^{N} a_{ijt}. \tag{2}$$

The parameter α scales the wage that workers earn per unit of output produced. The parameter β represents the value of a unit of approval. A high value of β models for example that workers live in a company town, where they are highly dependent on colleagues' approval due to lack of alternative social contacts outside their work group. Finally, the costs of spending a unit of effort and the costs of giving a unit of approval are indicated by the parameters c and c', respectively.

The analysis focuses on games with a N-Prisoner's dilemma structure, where cooperation in the exchange of work effort is collectively desirable, but actors face incentives to free ride. This implies that loafing is more cost-effective than working and that everyone realizes a Pareto optimal collective benefit when everyone pulls his weight, or

$$\frac{\alpha}{N} < c < \alpha. \tag{3}$$

Similarly, exchange of approval is profitable for both participants, but there is at least some incentive to free ride on approval. Hence, the unit costs of approval provisions (c') are positive and lower than the unit benefit β. Formally,

$$0 < c' < \beta. \tag{4}$$

Then, cooperation in this game is problematic. The constituent one-shot game has a unique Nash equilibrium where all workers shirk and no approval is given. In this equilibrium, each player maximizes his utility given the behavior of all others.[4]

To model reciprocity in repeated games, I use the standard assumption of infinite repetition of the game with exponential discounting of future payoffs[5] (cf. Friedman, 1971, 1986; Taylor, 1987). The accumulated payoff u_i of actor i in the repeated game sums discounted payoffs over all iterations t, u_{it}. Formally,

$$u_i = \sum_{t=0}^{\infty} \tau^t u_{it}, \quad 0 < \tau < 1. \tag{5}$$

where τ is the discount parameter, i.e., the value of an actor interest in future payoffs. For simplicity, τ is assumed equal for all members of the group. The payoff of iteration t, u_{it}, ensues from the corresponding outcome as defined by equation (2) above.

MODEL ANALYSIS

Solution Criteria

Broadly, a solution of the game is a prediction for players' behavior that satisfies certain reasonable requirements. I use three straightforward criteria to identify solutions of the repeated team game. First, I only consider strictly *symmetrical* outcomes, i.e., outcomes in which every player follows the same strategy for the repeated game. Homogeneity of the group in individual characteristics implies that non-symmetrical solutions can be excluded, because there is no systematic reason why players with equal characteristics should follow different strategies.

[4]The payoff structure of this game is equivalent with the earlier game theoretical analysis (Flache, 1996; cf. Flache, Macy, Raub 2000). With unit wage $\alpha = 1$ the model also replicates the condition of the feasibility of bilateral exchanges of approval in the simulation model of Flache and Macy (1996).

[5]Alternatively, the game may be seen as an indefinitely repeated game such that actors know that after every decision round there is a certain probability that the game may end. For example, actors may at any time expect to find a new job with a certain probability.

The second solution principle is *individual rationality*. In game theoretical terms, individual rationality implies Nash equilibrium. Given the strategy of all other players, no member of the group can improve his payoff by a unilateral change of his strategy. Moreover, sanction threats are credible, i.e., it is actor's best strategy to carry out the sanction even after it failed to deter deviation. Technically, this implies that the solution of the game is a subgame perfect equilibrium (spe) (Selten, 1965, cf. Kreps 1990).

The third solution requirement is *efficiency* in terms of payoff dominance. Payoff dominance eliminates those spes from the set of possible solutions to which all players would unanimously prefer other spes (for more details, see Harsanyi, 1977, 116–119). Symmetry renders application of payoff dominance particularly simple. Symmetrical strategies generate the same expected payoff value for all players. Accordingly, the solution of the game is the symmetrical spe for which this value is maximal in the set of all possible symmetrical spes of the repeated game.

Trigger Strategies

The analysis uses a generalized form of so-called trigger strategies (Friedman, 1971, 1986), because these strategies combine three important features. First, trigger strategies model conditional cooperation, the mechanism that sustains reciprocity. Second, trigger strategies can provide an endogenous explanation of cooperation in social dilemmas consistent with the central solution requirement of individual rationality (Friedman, 1971, 1986). Finally, trigger strategies are relatively easy to analyze. In particular, the collective efficiency of a symmetrical trigger strategy can be computed straightforwardly, which greatly facilitates the application of payoff dominance.

Trigger strategies under imperfect information generate cooperative behavior in a *normal period* of the game, but as soon as the corresponding norm has been violated too much, the trigger strategy reverts to a sanction strategy for a subsequent *sanction period*. Cooperation is restored after the sanction period, but only as long as there is sufficient compliance. To address the tradeoff between strong ties and task performance, I distinguish three types of trigger strategies corresponding to the three forms of reciprocity norms, full cooperation, task cooperation, and relational cooperation. Full cooperation represents the norm to both work hard and approve of colleagues, resulting in simultaneous high task performance and high group cohesion. Task cooperation limits cooperation to the work game alone, whereas no approval is exchanged among members. Accordingly, task cooperation induces high task performance while the group is not cohesive. Finally, relational cooperation demands exclusively cooperation in the approval games, generating a highly cohesive team with zero task performance.[6]

Under *full co-operation*, σ_{wa}, actors trade both *work* and *approval* in return for others' work and approval. Individual rationality and collective efficiency allow the narrowing down of the range of strategies of full cooperation. To begin with, only strategies are of interest that punish any failure to approve of a colleague with the severest possible sanction—immediate full and eternal defection by all other players. Due to perfect information in the approval games, every deviation from the norm to approve is a perfect indication of an intended violation of the norm. Accordingly, any weaker sanction unnecessarily limits the range of conditions under which this deviation can be deterred by full cooperation. At the same time, task uncertainty implies that a certain degree of lenience with respect to deviations in the work game is required to optimize efficiency. Otherwise, unintended failures to contribute may generate too many sequences of mutual punishment. Lenience in the sanctions imposed may mitigate the problem, but too much lenience curtails the effectiveness of the sanction. This, in turn, invites exploitation by shirkers (cf. Kreps, 1990).

Following Bendor and Mookherjee (1987) I use two parameters of a full cooperation trigger strategy to model the trade off between lenience and deterrence, the cutoff level l and the sanction time s. In the strategy $\sigma_{wa}(s, l)$, ego fully cooperates throughout a normal period, but he reverts

[6]A fourth trigger strategy of interest might be called "purely social control." Under purely social control, shirkers are exclusively sanctioned by the withdrawal of colleagues' approval, while enforcers continue to work in the sanction period. Under imperfect information, it might be of interest to take this strategy into account, because it promises to avoid the efficiency losses that task uncertainty entails due to mutual punishment in the work game. However, on closer inspection it turns out that under task uncertainty, efficiency losses in the work game are still considerable, even when control is purely social. The reason is that with a purely social control strategy, rational workers who are sanctioned by their colleagues have no incentive to contribute to the work game or to approve of their peers before the sanction period is over. Sanction credibility enforces that cooperative behavior in the sanction period can not alleviate the punishment. As a consequence, task performance under purely social control gradually declines to a level where the number of shirkers stabilizes at a level reflecting the strength of task uncertainty. Obviously, it greatly complicates the analysis to find the equilibrium conditions for this kind of strategy as compared with simpler strategies where task and ties are either disentangled (task cooperation and relational cooperation) or fully linked (full cooperation). To assess the consequences of purely social control, I conducted explorative numerical analyses of equilibrium conditions. These analyses indicated that the qualitative results of the present study do not change when strategies of purely social control strategies are considered. The corresponding equilibria are only under a small range conditions payoff superior to any of the competing solutions of full cooperation, task cooperation, or relational cooperation. Accordingly, I abstain in this article from a full-scale analysis of purely social control.

to a sanction period of exactly s iterations as soon as in the normal period the group output falls below the strategy specific cut-off level l. After the sanction period, ego starts a new normal period with an initial round of unconditional full cooperation. Individual rationality implies that there is no need to consider full cooperation strategies that only withdraw task contribution to impose a sanction. *If* a sanction is imposed, it should be as severe as possible to maximize deterrence. However, efficiency might yield a reason to consider sanction strategies of "purely social control" that exclusively withdraw approval to sanction but continue to work. These strategies might maintain a relatively high group output, because they avoid costly "echo effects" in task sanctions. However, I do not take into account purely social control, because exploratory numerical studies showed that this does not change qualitative results while it greatly complicates analysis of the corresponding equilibria (for more detail, cf. note 6).

Under a strategy of task cooperation σ_{ww}, cooperative behavior is restricted to the work game alone. Ego only demands that a sufficient number of effective contributions to the group task be made in every normal period. In return, ego works hard in the corresponding period, but he does not invest peer approval. To optimize sanctioning policies in the work game, strategies of task cooperation, $\sigma_{ww}(s, l)$ vary in their sanction time s and the cut-off level l, like strategies of full cooperation.

Under relational cooperation, σ_{aa}, a group member demands to be approved of by all colleagues in exchange for his approval of the peers. Again, perfect monitoring in approval games implies that only a strategy maximizes the range of conditions for individual rationality that responds with full and eternal punishment to every observed failure to approve. Accordingly, the analysis deals only with this particular strategy of relational cooperation.

Efficiency and Individual Rationality of Trigger Strategies

Relational cooperation only involves games with perfect monitoring. Accordingly, conditions for the individual rationality of relational cooperation follow from Friedman's theorem (1971; 1986, 88–89). Friedman showed that universal play of trigger strategies such as σ_{aa} constitutes a subgame perfect equilibrium, if and only if actors are sufficiently interested in future payoffs. For relational cooperation, this yields condition (6)

$$\tau > \tau^* = \frac{T_{aa} - R_{aa}}{T_{aa} - P_{aa}} = \frac{c'}{\beta}. \tag{6}$$

The symbol T_{aa} in equation (6) represents the payoff from receiving universal approval without costs of reciprocation. R_{aa} indicates the payoff ego derives from cooperation in the exchange of approval for approval with every other member of the group. Finally, $P_{aa} = 0$ is the payoff an actor obtains from the punishment outcome of universal full defection. The rightmost term in equation (6) obtains when the game payoffs are substituted according to the definitions of the team game (2)–(4), i.e., $T_{aa} = (N-1)\beta$, $R_{aa} = (N-1)(\beta - c')$ and $P_{aa} = 0$.

Condition (6) expresses the trade-off between short-term gain of unilateral defection $(T_{aa} - R_{aa})$ and the ensuing long-term loss of rewards from the exchange $(T_{aa} - P_{aa})$. In relational cooperation, this simply translates into the requirement that the discount rate exceeds the ratio of the costs of approving to the unit value of approval. If equation (6) is satisfied, the accumulated payoff every group member obtains from universal relational cooperation, $u_i(\sigma_{aa})$, is obtained according to (5). Hence

$$u_i(\sigma_{aa}) = \frac{R_{aa}}{1-\tau} = \frac{(N-1)(\beta - c')}{1-\tau} \tag{7}$$

Friedman's theorem also yields a first necessary condition for individual rationality of full cooperation. Full cooperation needs to deter full defection in both work and approval games. Under full cooperation, a deviant knows that eternal punishment is unavoidable after any failure to approve. Hence, it is then ego's best deviation to immediately defect to the largest possible extent, i.e., to shirk and to shun all colleagues. Accordingly, any full cooperation strategy $\sigma_{wa}(s, l)$ can only be a spe if every actor's interest in future payoffs, τ, exceeds the critical level $\tau*$, where

$$\tau > \tau^* = \frac{\hat{T}_{wa} - \hat{R}_{wa}}{\hat{T}_{wa} - P_{wa}}. \tag{8}$$

The symbol $\hat{T}_{wa}$ refers to the expected payoff from one round of unilateral maximal deviation under full cooperation, $\hat{T}_{wa} = (1-\varepsilon)\frac{\alpha(N-1)}{N} + (N-1)\beta$. The symbol $\hat{R}_{wa}$ denotes the expected payoff for a compliant player from one round of universal full cooperation, $\hat{R}_{wa} = (1-\varepsilon)\alpha - c + (N-1)(\beta - c')$. Finally, the payoff for one round of universal full deviation is zero by definition, $P_{wa} = 0$. Condition (8) is independent from the actual sanction profile (s, l). This reflects that the condition only deals with deterrence of deviations in the approval part of the game where monitoring is perfect even under task uncertainty.

To guarantee individual rationality of full cooperation, $\sigma_{wa}(s, l)$ and task cooperation, $\sigma_{ww}(s, l)$, both strategies need to ensure additionally that optimal unilateral deviations in the *work game* do not pay. To also optimize efficiency, the strategy profile s^*, l^* is sought that for both σ_{ww} and σ_{wa} maximizes the related expected payoff of $u_i(\sigma_{ww}(s^*, l^*))$ or $u_i(\sigma_{wa}(s^*, l^*))$, subject to the constraint that the corresponding trigger strategy constitutes a subgame perfect equilibrium.[7] Spe conditions for deviations in the approval game follow from equations (6) and (8). For calculation of expected payoffs of trigger strategies and for evaluation of the constraint that work deviations do not pay, I adapted an efficient *numerical* algorithm from Bendor and Mookherjee (1987) that solves the optimization problem for a given set of conditions $(\alpha, \beta, c, c', N, \varepsilon, \tau)$. The algorithm needs to test only one condition per cutoff l and per class of strategy σ_{ww} or σ_{wa} to ensure individual rationality for every possible strategy with the corresponding cut-off level. This is the condition that the trigger strategy with *eternal punishment* and cut-off level l is individually rational. Intuitively, the reason is that eternal punishment maximizes the expected loss from the sanction that a deviant faces. If and only if this loss is sufficient to deter unilateral defection, there will be some finite sanction period s that guarantees a subgame perfect equilibrium for the given strategy with cut-off level l. Technically, adaptation of Bendor and Mookherjee's result yields theorem 1. The theorem applies to both full cooperation and task cooperation. Accordingly, subindices wa and ww are dropped in the notation.

Theorem 1. A spe for a trigger strategy $\sigma(s, l')$ with cut-off level l' can only exist, when the corresponding trigger strategy with infinite sanction time, $\sigma(\infty, l')$, constitutes a spe. For this strategy to be an spe $\sigma(\infty, l')$ it is necessary that

$$\frac{\hat{T}_w - \tau q_R \hat{T}_w + \hat{R}(\tau q_T - 1)}{\tau q_R - 1} \geq 0, \tag{9}$$

Proof: see appendix.

The proof in the appendix shows how condition (9) follows if $s = \infty$ is used to find the corresponding individual rationality constraint for cut-off level l. This is the constraint that under the trigger regime *(s,l)*, individuals' expected payoff from continued work contribution is always lower or equal to the payoff they could obtain with their best possible unilateral deviation in the work game. The symbol $\hat{R}$ in (9) refers to the expected payoff from one round of universal cooperation, which is $\hat{R}_{ww} = (1 - \varepsilon)\alpha - c$ for task cooperation and $\hat{R}_{wa} = (1 - \varepsilon)\alpha - c + (N - 1)(\beta - c')$ for full cooperation. The symbol $\hat{T}_w$ indicates the expected payoff from one round of unilateral shirking, $\hat{T}_{ww} = (1 - \varepsilon)\frac{\alpha(N-1)}{N}$ for task cooperation and $\hat{T}_{w,wa} = (1 - \varepsilon)$

[7] Due to symmetry, trigger strategies always constitute a subgame perfect equilibrium, if they satisfy the conditions for Nash-equilibrium. The proof is given by Friedman (1986).

$\frac{\alpha(N-1)}{N} + (N-1)(\beta - c')$ under full cooperation. Finally, the symbols q_R and q_T in (9) refer to the probability that no sanction phase is triggered in a normal period after universal work and after unilateral shirking in the work game, respectively. These probabilities are obtained from the binomial distribution as $q_R(1-\varepsilon, l, N)$ and $q_T(1-\varepsilon, l, N-1)$, the probabilities that at least l actors will produce output when all N members contribute with success rate of $(1-\varepsilon)$, and when $N-1$ members work and the focal actor deviates unilaterally, respectively.

The second operation of the numerical procedure is to calculate and compare the optimal expected payoffs from universal cooperation that can be obtained for those cut-off levels l' that satisfy condition (9). The optimal profiles $\sigma(s, l')$ can be found by inspection of only one trigger strategy per cut-off level l. This is the strategy with the most lenient sanction time s that is just restrictive enough to deter deviations under a cut-off level l'. Intuitively, the reason is that as long as sanctions are severe enough to guarantee individual rationality, it is in the best interest of every group member to reduce as much as possible the expected amount of punishment over the course of the game. Technically, Theorem 2 asserts that efficiency is always maximized when s is minimized, subject to the constraint of individual rationality and given a constant cut-off level l.

Theorem 2. If for a given cut-off level l' the trigger strategy $\sigma(\infty, l')$ is in equilibrium for infinite sanction time s, then the payoff dominant spe for the cut-off level l' is the one with the smallest sanction time $s = s^*(l')$ of all spe's with $\sigma(s, l')$. This optimal s is

$$s^*(l') = \mathrm{Ceil}\left(\frac{\ln\left(\frac{\hat{R} - \tau q_T \hat{R} + (\tau q_R - 1)\hat{T}_w}{\hat{R} - q_T \hat{R} + (q_R - 1)\hat{T}_w}\right)}{\ln(\tau)}\right), \tag{10}$$

where Ceil(x) yields the smallest integer larger than or equal to x. Proof: see appendix.

The proof in the appendix shows how condition (10) derives from the effect of the sanction time s on the expected payoffs from optimal unilateral work defection, u_{-i}, and unilateral cooperation u_i. Shorter sanction time s does not affect the probabilities that sanctions are triggered in a normal period, but it reduces the expected duration of sanction periods over the entire game. This increases expected payoffs from both cooperation and unilateral defection. However, payoffs from unilateral defection benefit more, because shorter s also implies more frequent sanction periods, and in every sanction period shirkers gain initially from unilateral defection. Hence, there is a critical lowest sanction time s^*, below which the individual rationality constraint $u_i \geq u_{-i}$ can no longer be satisfied.

To summarize, using Theorems 1 and 2 and a given vector of parameters $(\alpha, \beta, c, c', N, \varepsilon, \tau)$, the algorithm finds the optimal spes for task cooperation and full cooperation and tests whether relational cooperation, σ_{aa}, likewise constitutes a spe for the given parameter vector (Condition 6). For full cooperation, the algorithm tests in addition the condition for deterrence of full defection, as seen in condition (8). Then, the expected payoffs of the optimal equilibria of each type of strategy are compared, and the best one is selected. If none of the trigger strategies is sustained by a spe, the solution for $(\alpha, \beta, c, c', N, \varepsilon, \tau)$ is full and eternal defection, with zero group performance and zero group cohension.

Aggregate Outcomes: Expected Performance and Expected Cohesion

To obtain comparative statics, *expected performance* and *expected cohesion* are measured on basis of the relative size of the range of discount levels, τ, that sustain the corresponding solutions. More precisely, the algorithm varies τ for a given set of conditions $(\alpha, \beta, c, c', N, \varepsilon)$ between $\tau = 0$ and $\tau = 1$ in steps of 0.01. For every level of τ, the corresponding solution of the game is identified and the ensuing expected performance $p(\tau)$ and expected group cohesion $p'(\tau)$ is measured. Overall expected performance and cohesion at $(\alpha, \beta, c, c', N, \varepsilon)$ are then computed as averages across the range of τ.

Expected performance is zero and expected group cohesion is one, if the solution of the game is relational cooperation for a particular level of τ. Expected group cohesion is zero when the solution is a task cooperation strategy. When the solution of the game is full cooperation or task cooperation, the expected group performance is obtained as the probability that a particular round of the game falls within a normal period, multiplied with the expected group output $(1 - \varepsilon)$ in a normal iteration. Technically,

$$p = \frac{(1 - \varepsilon)\hat{d}_R}{\hat{d}_R + s}, \tag{11}$$

where $\hat{d}_R$ refers to the expected duration of a normal period, $\hat{d}_R = 1/(1 - q_R)$. The probability to be in a normal period is obtained from the expected duration of a normal period relative to expected total length of normal period plus subsequent sanction period, $\hat{d}_R + s$. Expected cohesion, p', under full cooperation is obtained similarly. Expected cohesion in an iteration of a normal period is always one, whereas it is always zero in a sanction period. Accordingly, the average level of cohesion across the entire game equals the relative number of iterations that take place in a normal period, $p' = \hat{d}_R/(\hat{d}_R + s)$.

RESULTS

The traditional theory of compliant peer pressure suggests that higher dependence on peer approval from the group increases both cohesion and performance. In this view, effective informal control is the link between strong ties and performance. The weakness of strong ties, by contrast, implies that at least in certain regions of the parameter space dependence may boost cohesion but fail to foster or even reduce performance. In the following, I analyze this effect of actors' dependence, β.

The analysis departs from the baseline condition of task certainty ($\varepsilon = 0$), where social control effectively helps to solve free rider problems. In the following three sections, I present analytical results for the baseline scenario, numerical analysis to show how increasing task uncertainty erodes the effectiveness of social control, and demonstrate that dependence on peer approval may even undermine group performance in a highly severe social dilemma.

How Peer Pressure is Effective: Task Uncertainty

For the baseline condition of task certainty ($\varepsilon = 0$), results for the behavior of rational workers have been derived analytically (Flache, 1996; Flache et al., 2000). Increasing dependence on peer approval improves both cohesion and group performance in a large region of the parameter space. Moreover, the analysis showed that, contrary to the hypothesized failure of informal control, higher dependence *never* reduces performance. Theorem 3 formulates the corresponding proposition.

Theorem 3. Effects of dependence on peer approval, β, under task certainty ($\varepsilon = 0$)

In the repeated team game, increasing dependence on peer approval, β, always fosters expected cohesion. Moreover, when β exceeds a threshold level given by (15), dependence on peer approval also fosters performance. Below the threshold level, β has no effect on performance. More technically:

$$\frac{\partial p}{\partial \beta} = 0, \quad \text{if } \frac{\alpha - \frac{\alpha}{N}}{c - \frac{\alpha}{N}} > \frac{\beta}{c'}; \quad \frac{\partial p}{\partial \beta} > 0, \quad \text{otherwise}$$
$$\frac{\partial p'}{\partial \beta} > 0 \tag{15}$$

Proof: see Flache (1996, cf. Flache, Macy, Raub 2000).

Theorem 3 follows from Friedman's (1971, 1986) result for the individual rationality of trigger strategies under perfect information. Under perfect information, full cooperation simply adds the costs and benefits of the separate exchanges of work for work and approval for approval. This implies the turning point in the effect of dependence identified by Theorem 3. Beyond the turning point, peer approval is so valuable that conditions for individual rationality of relational cooperation are less restrictive than are conditions for task cooperation. Then, conditions for the combination of the two exchanges are likewise less restrictive than for task cooperation alone. As a consequence, performance in this region of the parameter space is solely based on full cooperation, causing the simultaneous increase of cohesion *and* performance as actors' dependence rises. Conversely, below the turning point, approval has so little value to group members that performance is predominantly based on task cooperation. Here, peer pressure is not needed to sustain performance, and higher dependence has no effect on group output.

How Task Uncertainty Erodes Peer Pressure

To demonstrate effects of task uncertainty, I consider a scenario in which workers face a serious free-rider problem in the work game. With $N = 10$, $\alpha = 1$ and $c = 0.5$, the marginal costs of a unit of effort are five times as large as the corresponding marginal benefit. Following Coleman (1990, 277) I assume that the costs of generating a unit of approval are small relative to potential control benefits, i.e., $c' = 0.05$, only one-tenth of the costs of contribution to the work task. Dependence on peer approval β varies in 100 equidistant steps between no dependence, $\beta = 0$, and a very high level of dependence, $\beta = 0.5$, where approval by one group member is sufficient to compensate costs of task contribution. Figure 1 shows the result. For comparison, task certainty ($\varepsilon = 0.0$) is analyzed together with moderate task uncertainty ($\varepsilon = 0.1$) and strong task uncertainty ($\varepsilon = 0.2$). The results are calculated with the numerical procedure described in the Model Analysis section of this article.

Figure 1 demonstrates how increasing task uncertainty gradually erodes the effectiveness of informal control. Under task certainty, ($\varepsilon = 0.0$), informal control is sufficiently strong to push group performance from a level of about $p = 0.5$ in groups with low interest in peer approval, up to a level of about $p = 0.8$ in groups whose members strongly depend on peer approval. However, in groups facing high task uncertainty ($\varepsilon = 0.2$), expected performance remains dramatically low, with less than $p = 0.25$ even in groups where peer approval is deemed highly valuable ($\beta = 0.5$). As predicted by the weakness of strong ties, the gradual decline in performance is not matched with a corresponding decline in cohesion. As interest in peer approval rises, cohesion soars, regardless of the level of task uncertainty. At all levels of ε, even moderate interest in peer approval ($\beta = 0.1$) suffices to boost cohesion up to about $p = 0.5$ from the initial level of zero cohesion with no interest in peer approval, and with $\beta = 0.5$ cohesion approaches its maximum level.

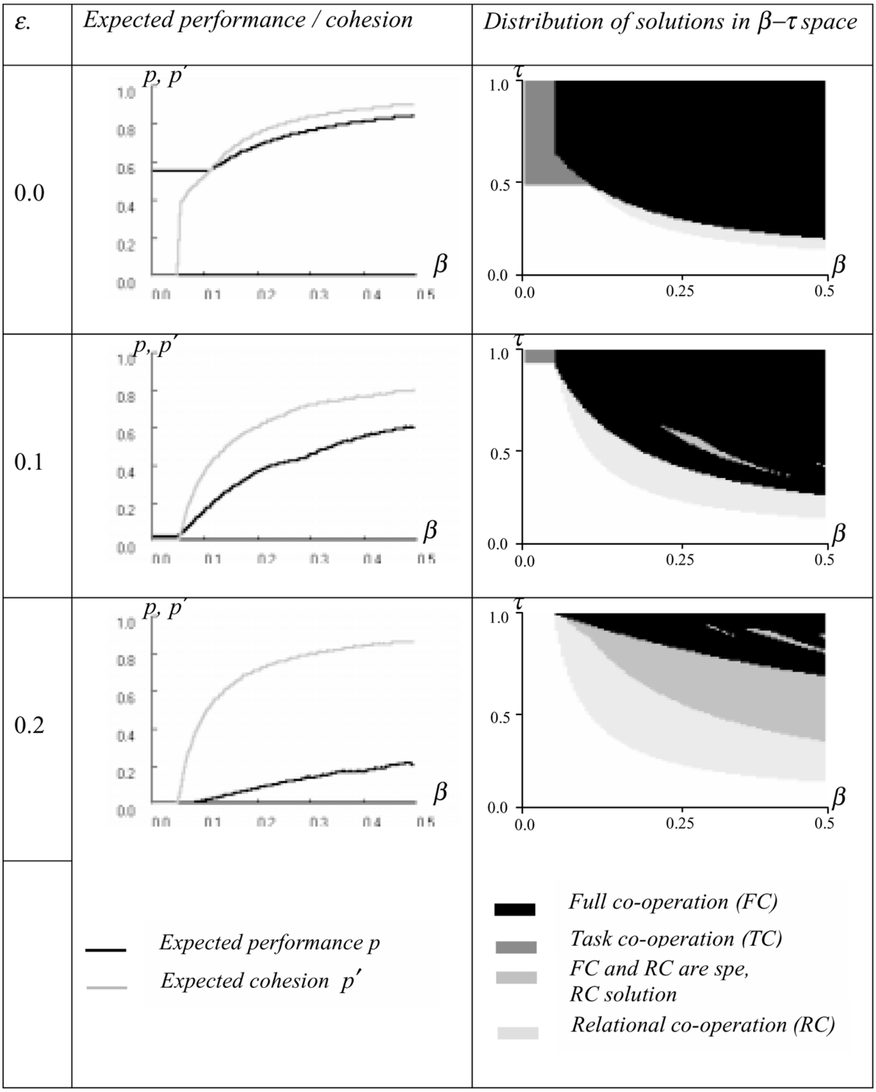

FIGURE 1 Effects of dependence on peer approval (β) on aggregate outcomes (left) and distribution of solutions in the β-τ parameter space (right) for three different levels of task uncertainty, ε. $N = 10$, $\alpha = 1$, $c = 0.5$, $c' = 0.05$. White regions in right part of the figure indicate full defection.

Inspection of the right part of Figure 1 reveals why task uncertainty undermines peer pressure despite the emergence of strong ties. As task uncertainty rises, the conditions become increasingly restrictive, under which full cooperation obtains at a particular level of β. With task uncertainty, the problem for full cooperation is that efficiency losses from mutual sanctions caused by work failure spill over into social relations. This may put a considerable pressure on social relations, compromising the efficiency of full cooperation relative to the efficiency of relational cooperation. Even when the group obtains full cooperation under moderate task uncertainty ($\varepsilon = 0.1$), mutual sanctions may drive the level of performance sustained down to not more than $p = 0.22$, a level that occurs, when actors are only moderately interested in peer approval but are sufficiently interested in future payoffs to render full cooperation attractive ($\beta = 0.11, \tau = 0.7$). Due to the spill-over effect, cohesion likewise reduces to not more than $p' = 0.39$ at this point in the parameter space. Clearly, with this strong pressure on social ties, full cooperation is only barely payoff superior to relational cooperation, where performance is zero but cohesion is at its maximum of $p' = 1$. Accordingly, relational cooperation increasingly dominates full cooperation, as task uncertainty rises. The right part of Figure 1 shows how with strong task uncertainty this occurs under a large range of conditions even when the competing regime of full cooperation is also individually rational. With task certainty, full cooperation would then prevail. Under task *un*certainty, relational cooperation predominates. As a consequence, strong ties form without effective peer pressure in these groups. While expected performance is as low as about $p = 0.25$ in highly dependent teams under strong uncertainty, expected cohesion attains almost its maximum level here.

Task Uncertainty Reverts Effects of Dependents in a Severe Dilemma

The result of Figure 1 clearly questions Homans' theory of compliant peer pressure in cohesive groups. At the same time, model effects fall short of the "weakness of strong ties" that Flache and Macy (1996) demonstrated for groups of adaptive agents. In simulations that used an almost identical baseline scenario as in Figure 2, they showed that higher dependence on peer approval not only failed to foster performance but also could actually reduce performance at the expense of cohesion[8]. The spill-over effect from ties to task revealed by Figure 1 suggests that this may become a possibility for rational actors facing task uncertainty, when the cost:benefit ratio for work contributions further deteriorates.

[8]The original simulations (Flache and Macy, 1996, pp. 19) assumed task certainty ($\varepsilon = 0$) and lower costs of approval, with $c' = 0.01$. The assumption of higher costs of approval is inessential for the qualitative result of the present analysis. Robustness tests revealed the same qualitative effects with $c' = 0.01$.

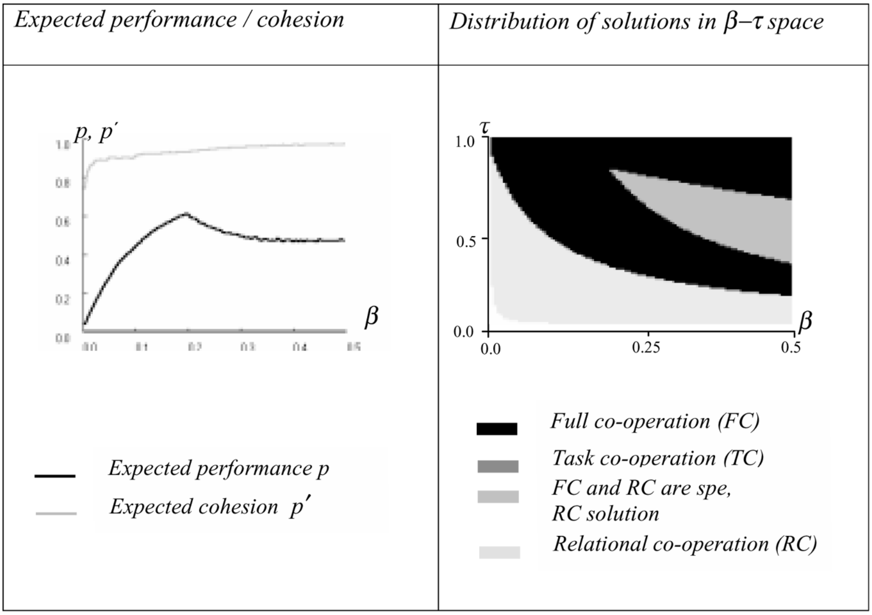

FIGURE 2 Effects of dependence on peer approval (β) on aggregate outcomes (left) and distribution of solutions in the β-τ parameter space (right) for severe social dilemma ($\alpha = 1, c = 0.85$), and moderate task uncertainty, $\varepsilon = 0.01$. $N = 10$, $\alpha = 1$, $c' = 0.05$. White regions in right part of the figure indicate full defection.

To demonstrate this possibility, I adapted the baseline scenario such that shirking becomes highly attractive due to excessive costs of compliance ($c = 0.85$). With this cost level, high performance is hard to sustain but still collectively efficient, i.e., ($\alpha > \mathrm{c}$). At the same time, full cooperation requires a highly restrictive sanction regime in order to secure performance. It can be expected that the spill-over of efficiency losses from task to ties dramatically curtails the attractiveness of full cooperation as compared with relational cooperation, as soon as actors gain interest in peer approval. To demonstrate the problem, I replicated the preceding analysis with $c = 0.85$ and a very low level of task uncertainty ($\varepsilon = 0.01$). All other conditions remained unchanged. Figure 2 shows the results.

Figure 2 reveals how in a severe social dilemma even marginal task uncertainty reverts the effect of dependence. Consistent with Homan's theory, higher dependence on peer approval increases task performance, but only below a level of $\beta = 0.2$. Beyond this turning point, further dependence on peer approval undermines performance rather than sustains it. The right part of Figure 2 shows why this happens. Higher dependence always widens the range of conditions under which full cooperation is individually rational. However, at the same time, relational cooperation increasingly dominates full cooperation as β increases. The net effect is that eventually the area begins to shrink in which full cooperation is attained by the group.

Closer inspection shows that two opposing effects of actors' interest in future payoffs, τ, cause the increasing dominance of relational cooperation. These effects of τ are best explained when a fixed level of β is considered. With $\beta = 0.4$, full cooperation dominates relational cooperation in groups facing a long shadow of the future ($\tau > 0.72$) and in groups with low interest in future payoffs ($\tau < 0.41$). The first effect of τ determines the lower bound of this region. At $\tau = 0.21$, full cooperation becomes sustainable, but at this low level of τ strong deterrence of deviations is required. In this range, only the full cooperation strategy is sustainable that imposes the most restrictive cut-off level of $l = 10$, combined with the optimal sanction time $s = 1$. With $\sigma_{wa}(1, 10)$, higher interest in future payoffs improves the utility of relational cooperation more than the utility of full cooperation. The reason is that relational cooperation yields continuous rewards, while the payoff stream of full cooperation is disrupted by sanction phases with zero payoff. Accordingly, full cooperation is more attractive for players with low interest in future payoffs τ, who are mainly interested in the early phase of the game, before the first sanction phase is entered. As soon as τ exceeds a level of 0.41, relational cooperation therefore becomes superior to the full cooperation of $\sigma_{wa}(1, 10)$.

The second effect of τ works in the opposite direction. Sanctions needed to sustain full cooperation become less restrictive with higher interest in the future. At $\beta = 0.4$, the cut-off level l drops from $l = 110$ to $l = 79$, as soon as interest in the future exceeds $\tau = 0.72$. Correspondingly, efficiency losses rapidly decline and beyond $\tau = 0.72$, full cooperation payoff dominates mere relational cooperation. The net effect of β on performance results from how dependence shapes the upper and the lower bound of the region in which relational cooperation prevails. As dependence increases, both thresholds decline, but the effect of β is stronger on the lower bound than on the upper bound. Hence, peer pressure increasingly loses ground to relational cooperation and performance declines.

DISCUSSION AND CONCLUSION

Recent research (Flache, 1996; Flache and Macy, 1996) suggests a "weakness of strong ties." Contrary with the prevalent view of the literature, this research argues that strong social ties may undermine group solidarity in a social dilemma rather than to foster a solution on basis of informal control. In a nutshell, the argument focuses on the desire of actors to obtain social rewards, such as affection or approval, from other group members. Previous work overlooked that this desire may often compromise actors' willingness to impose social control. Accordingly, so the argument goes, informal control may flow into the maintenance of strong ties at the expense of the common good.

This article strengthened and generalized the argument. While the original analysis derived the failure of informal control only for "backward-looking" actors with extremely low cognitive capacity, this article assumes perfect rationality. In the original study, informal control was predicted to fail because for backward-looking actors the lower coordination complexity of bilateral exchanges favors cooperation in interpersonal ties relative to more complex groupwise cooperation. This study revealed an alternative mechanism that causes social control to fail. Imperfect information in terms of task uncertainty can generate the result even when group members are modelled as strategically rational decision makers.

Particularly in work organizations, task uncertainty may often put informal control under pressure. Task uncertainty may cause sequences of mutual sanctions that increase costs of control and, accordingly, reduce the attractiveness of investment in peer pressure. The game theoretical analysis of this article confirmed that larger task uncertainty may increase the gap between common good production and group cohesion. In groups facing an extremely severe social dilemma, higher dependence on peer rewards makes groups more cohesive but less productive, consistent with the hypothesized weakness of strong ties. In a more moderate social dilemma, task uncertainty does not revert the effect of dependence, but it can still render social control virtually ineffective. Moreover, the game theoretical model showed that failure of informal control may be the optimal solution for rational agents. This leads beyond Flache and Macy's (1996) simulations of adaptive agents, where actors stumbled into the suboptimal outcome of collective action failure that rational agents can avoid under the same conditions (Flache, 1996; Flache, Macy, Raub, 2000).

While these results open an intriguing new possibility for theories of social control, the study rests on a number of simplifications that need careful consideration in future work. Previous group research points to four complications to be inspected. Production norms in work groups may not be directed at output maximization, group dynamics may alternate between phases of cohesion and phases of compliance, groups are not homogeneous in formal and informal status, and, finally, social ties consist not only of reward exchange. These complications do not necessarily limit the conclusions, but they may open up promising directions for future research.

The model assumes that output maximization constitutes a common interest of group members. However, Homans' (1951) case of the bank wiring room documents that production norms may evolve that demand from members an intermediate rather than maximal level of effort. Petersen (1992) indicates two plausible model extensions that address the intermediate effort norms in future research. Petersen's analysis assumes that workers' effort is continuous rather than discrete, and the marginal benefit of group output declines in effort. With this, the most efficient production norm imposes an intermediate effort level that maximizes net utility rather than total effort. At the same time, this does not change the basic logic of the weakness of strong ties. Even with intermediate effort levels, workers face incentives to shirk and social pressures are both needed to sustain compliance and suffer from task uncertainties.

Group research also revealed a dynamic form of intermediate output norms not captured with the present model. A group may develop an emergent cycle in which time periods with priority for work alternate with time periods dominated by social activity, another pattern described in Homans' (1951) case of the bank wiring group. Future modelling may explore how this pattern can be explained within the repeated team game framework. It seems plausible that individuals' experienced effort costs are not constant but increase gradually in periods of ongoing work and decline again in periods of rest. With this, individual rationality may sustain efficient norms that coordinate group–wise switches from task cooperation to relational cooperation and back at the moments when subjective effort costs exceed or fall below critical levels. However, while this elaboration promises to greatly enrich the behavioral patterns generated by the analysis, it retains the mechanism that causes the potential weakness of social control. Particularly towards the end of work phases, when fatigue rises, peer pressure may be needed to deter untimely shirking. Again, deviants may then utilize others' dependence on peer rewards to insulate themselves from these social pressures.

The present study precludes informal status differentiation, a phenomenon well known from group research (Homans, 1951). Both the effects and the emergence of informal status hierarchies are consistent with the repeated game model if the present assumptions of group homogeneity and discrete approval levels are relaxed. Bendor and Mookherjee (1987) showed how heterogeneity in individual effort costs may give rise to individually rational production norms that divide the group into workers and shirkers. Future work may explore how approval exchanges could explain the emergence of informal status hierarchies in a divided group. Workers become high status members when social control strategies direct approval to workers and withhold it from shirkers. However, with continuous approval levels, new forms of a rational weakness of strong ties may arise in status hierarchies. In particular, it may become individually rational for isolated shirkers to exploit workers' dependence on peer rewards and to offer them exchange of approval for approval at an asymmetrical rate of return. The strategy compensates workers for their efforts and simultaneously alleviates the isolation otherwise imposed on shirkers.

Formal hierarchical status differences are a further mechanism that may preclude collective action failure, for instance when a supervisor in a work team sanctions shirkers and rewards contributors. The present analysis does not take formal hierarchy into account. However, it allows to identify new conditions for the effectiveness of formal control mechanisms. The more susceptible a group is to the weakness of strong ties when hierarchical control is absent, the more costly or the less effective formal control may be. Similarly, the hypothesis of a weakness of strong ties may help to understand certain features of formal control mechanisms. Organizations may be particularly inclined to suppress strong bilateral ties or to encourage compliant control if the situation of a group is conducive for the failure of informal peer pressure.

Finally, the predicted conflict between social relations and collective exchanges may occur not only in ties that consist of exchanges of peer rewards, but also when network relations channel communications. For example, in research teams, a "communication dilemma" (Bonacich, 1992) arises when status gains or bonus payments reward exceptional individual performance. The team as a whole may benefit when all members share their knowledge with the group. At the same time, individuals face incentives to collude in dyadic exchanges of information or in small cliques. Whether members trade knowledge multilaterally or bilaterally, the exchanges require cooperation among participants. However, team performance may suffer because cooperation in collusive bilateral exchanges may be more easily attained due to better monitoring and less uncertainty. As a consequence, members may be distracted from the collectively superior solution of sharing knowledge with the group as a whole, precluding multilateral exchanges even when the latter are more efficient.

To conclude, this article adds to the theoretical evidence that informal control as a solution for social dilemmas may be overrated. Clearly, the analysis is preliminary and rests on a number of simplifying assumptions. At the same time, it considerably generalizes the argument beyond the previous learning theoretical underpinning of the possibility of a weakness of strong ties. This is of interest both for organizations facing social dilemmas and for researchers studying the dilemmas. Organizations may be well advised not to rely too easily on the traditional view that strong ties facilitate group solidarity. Researchers might feel encouraged to test this possibility in empirical studies of group solidarity in and beyond work organizations.

REFERENCES

Alchian, A., & Demsetz, H. (1972). Production, information costs and economic organization. *American Economic Review*, *62*, 777–795.

Axelrod, R. (1997). *The complexity of cooperation.* Princeton: Princeton University Press.

Axelrod, R. (1984). *The evolution of cooperation.* New York: Basic Books.

Bendor, J., & Mookherjee, D. (1987). Institutional structure and the logic of ongoing collective action. *American Political Science Review*, *81*, 129–154.

Bonacich, P. (1992). Communication networks and collective action. In W. B. G. Liebrand et al., (ed), *Social Dilemmas. Theoretical Issues and Research Findings* (pp. 225–245). Oxford: Pergamon Press.

Bush, R. R., & Mosteller, F. (1955). *Stochastic models for learning.* New York: Wiley.

Coleman, J. S. (1990). *Foundations of social theory.* Cambridge, Masssachuetts: Harvard University Press.

Coleman, J. S. (1994). A rational choice perspective on economic sociology. In N. J. Smelser and R. Swedberg (ed.), *The handbook of economic sociology* (pp. 166–180). Princeton: Princeton University Press.

Dawes, R. M. (1980). Social dilemmas. *Annual review of psychology*, *31*, 169–193.

Edwards, P. K., & Scullion, H. (1982). *The social organisation of industrial conflict.* Oxford: Basil Blackwell.

Festinger, L., Schachter, S., & Back, K. (1950). *Social pressure in informal groups.* New York: Harper and Row.

Flache, A. (1996). *The double edge of networks.* Amsterdam: Thesis Publishers.

Flache, A., & Macy, M. W. (1996). The weakness of strong ties: collective action failure in a highly cohesive group. *Journal of Mathematical Sociology*, *21*, 3–28.

Flache, A., Macy, M. W., & Raub, W. (2000). Do company towns solve free rider problems? A sensitivity analysis of a rational-choice examination. In: Raub, W. and J. Wessie (eds.), *The mathematical of durable reactions: Theoretical and empirical models for households and organizations.* Amsterdam: Thela Thesis.

Friedman, J. W. (1971). A non-co-operative equilibrium for supergames. *Review of Economic Studies*, *38*, 1–12.

Friedman, J. W. *Game theory with applications to economics.* New York: Oxford University Press.

Fudenberg, D., & Tirole, J. (1991). *Game theory.* Cambridge: MIT Press.

Gould, R. V. (1993). Trade cohesion, class unity and urban insurrection: Artisanal activism in the paris commune. *American Journal of Sociology*, *98*, 721–754.

Green, E. J., & Porter, R. H. (1984). Noncooperative collusion under imperfect price information. *Econometrica*, *52*, 87–100.

Harsanyi, J. C. (1977). *Rational behaviour and bargaining equilbrium in games and social situations.* Cambridge: Cambridge University Press.

Hechter, M. (1987). *Principles of group solidarity.* Berkeley, CA: University of California Press.

Heckathorn, D. D. (1989). Collective action and the second-order free-rider problem. *Rationality and Society*, *1(1)*, 78–100.

Heckathorn, D. D. (1990). Collective sanctions and compliance norms: A formal theory of group–mediated social control. *American Sociological Review*, *55*, 366–84.

Holländer, H. (1990). A social exchange approach to voluntary cooperation. *The American Economic Review*, *80*, 1157–1167.

Homans, G. C. (1951). *The human group.* New York: Harcourt Brace Jovanovich.

Homans, G. C. (1974). *Social behavior. Its elementary forms*. New York: Harcourt Brace Jovanovich.

Kandel, E., & Lazear, E. P. (1992). Peer pressure and partnerships. *Journal of Political Economy*, *100(4)*, 801–817.
Kitts, J., Macy, M. W., & Flache, A. (1999). Structural learning: attraction and conformity in task-oriented groups. *Computational and Mathematical Organization Theory*, *5(2)*, 129–146.
Kollock, P. (1993). An eye for an eye leaves everyone blind: cooperation and accounting systems. *American Sociological Review*, *58*, 768–786.
Kreps, D. M. (1990). *A Course in Microeconomic Theory.* New York: Harvester.
Loch, H. L., Huberman, B. A., & Stout, S. (2000). Status competition and performance in work groups. *Journal of Economic Behavior and Organization*, *43*, 35–55.
Lott, A. J., & Lott, B. E. (1965). Group cohesiveness as interpersonal attraction. *Psychological Bulletin*, *64*, 259–309.
Macy, M. W. (1989). "Walking out of social traps. A stochastic learning model for the prisoner's dilemma." *Rationality and Society*, *2*, 197–219.
Macy, M. W. (1991). Learning to cooperate: Stochastic and tacit collusion in social exchange. *American Journal of Sociology*, *97*, 808–843.
Marwell, G., & Oliver, P. (1993). *The critical mass in collective action. A micro-social theory.* Cambridge: Cambridge University Press.
Oliver, P. (1980). Rewards and punishments as selective incentives for collective action: Theoretical investigations. *American Journal of Sociology*, *85*, 1356–75.
Olson, M. (1965). *The logic of collective action.* Cambridge, MA: Harvard University Press.
Opp, K., & Gern, C. (1993). Dissident group, personal networks and spontaneous cooperation: The east german revolution of 1989. *American Sociological Review*, *58*, 659–680.
Ostrom, E. (1990). *Governing the commons. The evolution of institutions for collective action*. Cambridge: Cambridge University Press.
Petersen, T. (1992b). Individual, collective and systems rationality in work groups: Dilemmas and nonmarket solutions. *Rationality and Society*, *3*, 332–355.
Raub, W. (1988). Problematic social situations and the large number dilemma. *Journal of Mathematical Sociology*, *13*, 311–357.
Seashore, S. E. (1954). *Group cohesiveness in the industrial work group.* Ann Arbor: University of Michigan Institute for Social Research.
Selten, R. (1965). Spieltheoretische behandelung eines oligopolmodells mit nachfrageträgheit. *Zeitschrift für die gesamte Staatswissenschaft*, *121*, 301–324, 667–689.
Spagnolo, G. (1999). Social relations and co-operation in organizations. *Journal of Economic Behavior and Organization*, *38*, 1–25.
Simon, H. A. (1982) (1955). Models of bounded rationality: Behavioural economics and business organisation 2, 239–258 (first published in 1955).
Taylor, M. (1987). *The Possibility of Cooperation.* Cambridge: Cambridge Unviersity Press.
Voss, T. (1985). *Rationale akteure und soziale institutionen.* München: Oldenbourg.
Wu, J., & Axelrod, R. (1995). How to cope with noise in the iterated prisoner's dilemma. *Journal of Conflict Resolution*, *39*, 183–189.

APPENDIX

Proof of Theorem 1

The expected payoff for the remainder of the game after universal cooperation in a normal period in round t is obtained by

$$u_i = \hat{R} + \tau q_R u_i + \tau^{s+1}(1 - q_R)u_i, \tag{A1}$$

where $\hat{R}$ refers to the expected payoff in round t, and q_R to the probability of continuation of the normal period. Rearranging of (A1) yields the explicit form

$$u_i = \frac{\hat{R}}{1 - \tau q_R - \tau^{s+1}(1 - q_R)}. \tag{A2}$$

The expected payoff u_{-i} for the remainder of the game that ensues after unilateral shirking for one round t in a normal period, followed by immediate return to the cooperative strategy, is

$$u_{-i} = \hat{T}_w + \tau q_T u_i + \tau^{s+1}(1 - q_T)u_i, \tag{A3}$$

where u_i is to be substituted according to (A1) and$\hat{T}_w$ and q_T refer to the expected one-shot payoff of unilateral defection and the probability for subsequent continuation of the normal period. According to Bellman's (1957) optimality principle for dynamic programming under exponential discounting, a strategy cannot be improved by any change in a repeated game if it is impossible to improve the strategy in one step (cf. Kreps, 1990, p. 798). Hence, the trigger strategy $\sigma(s, l)$ constitutes a spe if $u_i \geq u_{-i}$, because then it can not be improved by any unilateral deviation.
The above yields the limit for $s \to \infty$ of $u_i - u_{-i}$:

$$\lim_{s \to \infty} u_i - u_{-i} = \frac{\hat{T}_w - \tau q_R \hat{T}_w + \hat{R}(\tau q_T - 1)}{\tau q_R - 1}, \tag{A4}$$

This proves that condition (9) is necessary for trigger strategies with infinite sanction time, $\sigma(\infty, l)$, to be in equilbrium. To proof that for a particular cut-off level l, the corresponding trigger strategy can only be in equilibrium when (9) is satisfied, the difference $u_i - u_{-i}$ is calculated in (A5) for finite s.

$$u_i - u_{-i} = \frac{\hat{R} - \hat{T}_w - q_T \hat{R}\tau + q_R \hat{T}\tau + ((q_T - 1)\hat{R} + (1 - q_R)\hat{T})\tau^{s+1}}{1 - q_R\tau + (q_R - 1)\tau^{s+1}}. \tag{A5}$$

Accordingly, the partial derivative of $u_i - u_{-i}$ by the sanction time s is

$$\frac{\partial(u_i - u_{-i})}{\partial s} = \frac{(q_R - q_T)\hat{R}(\tau - 1)\tau^{s+1}\ln\tau}{(1 - q_R\tau + (q_R - 1)\tau^{s+1})^2} \tag{A6}$$

The r.h.s. expression in (A6) always yields a positive result. The numerator is positive, as it is a square. The denominator is positive, because $q_R - q_T > 0$, and by definition universal cooperation is payoff superior to universal defection (Prisoner's dilemma), hence $\hat{R} > 0$. Finally, both $(\tau - 1)$ and $\ln\tau$ are negative, and τ^{s+1} is positive, as $0 < \tau < 1$. This implies that the difference $u_i - u_{-i}$, always increases in the sanction time s. Hence, $u_i - u_{-i}$ can never be positive, if it is not positive for $s = \infty$. Q.E.D.

Proof of Theorem 2

From (A2) it follows that the partial derivative of u_i by sanction time s is given by

$$\frac{\partial u_i}{\partial s} = \frac{(1 - q_R)\hat{R}\tau^{s+1} \ln \tau}{\left(1 - q_R\tau + (q_R - 1)\tau^{s+1}\right)^2} \tag{A7}$$

The proof of Theorem 1 implies that under positive task–uncertainty ($0 < \varepsilon < 1 \Leftrightarrow 0 < q_R < 1$), the derivative given by (A7) *is always negative*. Hence, the best individually rational trigger strategy for a fixed cut-off level l is the one with the smallest sanction time that still satisfies the condition for individual rationality. To find the corresponding sanction time, solve the equation $u_i = u_{-i}$ as given by (A2) and (A3) for s. This yields the (non-integer) sanction time s^* at which payoffs from the one step deviation balance payoffs from cooperation. Hence, the optimal sustainable sanction time for a given cut-off level is the smallest integer larger than s^*, which yields the term given by (10). Q.E.D.